

Review

Comprehensive Management of Severe Burn Injuries: A Multidisciplinary Approach from Resuscitation to Rehabilitation

Maryum Merchant ^{1,*} , Scott B. Hu ¹, Chris Miller ¹, Tamana Ahmadi ¹, Edwin Garcia ² and Malcolm I. Smith ¹¹ Department of Pulmonary/Critical Care, University of California Los Angeles, Los Angeles, CA 90095, USA; scotthu@mednet.ucla.edu (S.B.H.)² Grossman Medical Group, West Hills, CA 91307, USA

* Correspondence: mmerchant@mednet.ucla.edu

Abstract: Severe burns are among the most traumatic injuries, characterized by tissue damage, systemic inflammation, significant fluid shifts, and a high risk of complications such as infections, organ failure, anemia, malnutrition, and psychological trauma. This article reviews recent literature from the PubMed and Google Scholar databases to outline critical components of burn care, from initial resuscitation and stabilization through rehabilitation. Key topics include early airway management to prevent respiratory compromise, meticulous fluid resuscitation to maintain tissue perfusion while avoiding complications like fluid overload, and optimal pain management. It also discusses nutritional support tailored to the burn patient's hypermetabolic state and surgical techniques like early debridement and skin grafting. Beyond physical recovery, the review emphasizes the importance of addressing the psychological impact of burn injuries, including depression, anxiety, and post-traumatic stress, which can significantly affect long-term outcomes. By integrating the expertise of a multidisciplinary team with a personalized approach and practical recommendations, this review aims to provide clinicians with a comprehensive framework for managing severe burns, from the initial emergency response to the challenges of inpatient care and, finally, rehabilitation.

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Keywords: intensive care; critical care; severe burns; fluid resuscitation; inhalational injury; infection control; skin grafting; wound debridement; nutritional support; hypermetabolic state; pain management; anemia in burn patients; blood transfusions; psychological impact of burns; delirium and agitation; burn center transfer; surgical management of burns; sepsis in burn patients; advanced burn wound dressings; tissue engineering

1. Introduction

Severe burn injuries pose a significant global health challenge due to their high morbidity, mortality, and long-term physical and psychological consequences. Severe burns are defined by extensive tissue damage, often involving more than 20% of the total body surface area (TBSA), or by their location in critical areas such as the face, hands, feet, or genitals [1]. Additionally, burns complicated by inhalational injury, chemical exposure, or high-voltage electrical trauma are classified as severe and require immediate specialized care [2]. The pathophysiology of severe burns is unique because it involves not only local tissue destruction but also systemic effects, including the development of an extremely dys-regulated inflammatory response characterized by capillary leakage and a hypermetabolic state that can persist for months [3]. These factors contribute to a high risk of complications such as sepsis, multi-organ failure, and prolonged hospitalization.

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The management of severe burns is complex, requiring a multidisciplinary team and a coordinated approach that focuses on acute and critical care management, surgical intervention, and long-term rehabilitation. Initial care focuses on stabilizing the patient, with priority given to securing the airway, ensuring adequate ventilation, and initiating fluid resuscitation to counteract hypovolemic shock. Early surgical debridement and wound closure are critical for reducing infection risk and promoting healing, while advanced techniques such as skin grafting and the use of biological or synthetic skin substitutes have revolutionized wound management. Additionally, these patients experience significant psychological distress, including depression, anxiety, and post-traumatic stress, which can affect recovery and quality of life. Addressing these psychological aspects, alongside physical rehabilitation, is essential for holistic patient care.

This article provides a comprehensive review of current evidence, best practices, and practical insights in the management of severe burns, drawing from recent literature, including meta-analyses, randomized controlled trials, and clinical guidelines. It covers key topics such as fluid resuscitation strategies, nutritional support tailored to the hyper-metabolic state, infection prevention and treatment, and the management of anemia and blood transfusions. The review also explores emerging therapies and innovations, such as the use of high-dose vitamin C and continuous renal replacement therapy (CRRT), which hold promise but require further investigation. This article aims to equip clinicians with the knowledge and tools needed to deliver optimal care to burn patients, from the initial emergency response to the challenges of inpatient care and rehabilitation.

2. Method

We searched the literature using PubMed and Google Scholar with a combination of keywords, including “burn” and “critical care” OR “intensive care”, combined with topic-specific terms for each section (e.g., “nutrition” for the section on nutritional management, “fluid resuscitation” for fluid therapy, etc.).

We limited our search to articles published within the last five years to ensure current references. The studies focused on adult patients (≥ 18 years), with a particular emphasis on meta-analyses, randomized controlled trials (RCTs), clinical guidelines, and high-quality review articles. Additionally, the reference lists of selected review articles and meta-analyses were manually screened to identify supplementary sources of high relevance. Written informed consent was obtained from the participant for the publication of her images.

3. Defining Severe Burns

Burn injuries occur when skin encounters a heat source, which can include high temperatures, electricity, friction, radiation, and chemicals. Each etiology produces distinct burn types with unique characteristics, risks, and management considerations (Table 1). When defining the severity of burns, several factors are considered, including the location, depth, and extent of the burns, the temperature of the heat source, and the duration of exposure. Additional critical factors include the patient’s comorbidities, which can significantly influence the clinical outcome. One of the key elements to consider when categorizing burns is the depth of the burn. Third-degree burns (also known as full-thickness burns) affect the epidermis and dermis skin layers and result in a leathery, stiff, and dry appearance (see Figures 1–4). When burns involve the tissues beneath the skin, such as fascia, bones, and tendons, they are classified as fourth-degree burns. Severe burns are defined not only by the entire thickness of skin damage and soft tissue injury but also by the extent of total body involvement, reported as a percentage and estimated by applying estimation methods such as the rule of nines, the rule of palms, or the Lund–Browder chart. See Table 2 for details on these estimation methods, which were developed in the late 1800s

and are still widely used today [4]. The percentage describing the burn injury’s extent not only determines disease severity but also guides initial fluid resuscitation, nutritional needs, infection control practices, and other key aspects of burn care. Misestimating burn size may lead to inappropriate patient transfers or inaccurate fluid resuscitation.

Table 1. Characteristics of different types of burns.

Type of Burn	Cause	Tissue Damage	Key Characteristics	Common Complications
Electrical Burns	Contact with electrical current (high or low voltage)	Deep tissue, muscle, nerves, and bones	-Entry and exit wounds	deep internal injuries despite minimal surface damage -Possible cardiac arrhythmias, cardiac arrest -Neurological damage -Rhabdomyolysis and acute kidney injury (AKI) -Compartment syndrome
Chemical Burns	Exposure to strong acids, alkalis, or corrosive substances	Skin and deeper tissues depending on chemical type and duration	-Acid burns cause coagulation necrosis -Alkali burns cause liquefactive necrosis (deeper tissue damage)	-May continue to worsen until neutralized -Systemic toxicity -Respiratory complications (if inhaled) -Delayed wound healing
Friction Burns	Rapid skin abrasion from contact with a rough surface (e.g., road rash)	Superficial to deep skin layers	-Combination of abrasion and heat burn -May have embedded debris in the wound	-High risk of infection -Secondary infection -Scarring and pigmentation changes -Possible nerve damage
High-Temperature Burns (Thermal Burns)	Contact with flames, hot liquids, steam, or hot objects	Varies by temperature and duration; can affect epidermis, dermis, and deeper tissues	-Redness, blistering, or charring -Classified as first-, second-, or third-degree burns -Painful unless nerve endings are destroyed (full-thickness burns)	-Fluid loss and shock -Infection and sepsis -Scarring and contractures
Radiation Burns	Exposure to ionizing radiation (e.g., sunburn, radiation therapy, nuclear exposure)	Skin and deeper tissues depending on radiation dose and duration	-Erythema and peeling in mild cases -Blistering and ulceration in severe cases -Delayed onset (may appear hours to days later)	-DNA damage and increased cancer risk -Delayed wound healing -Secondary infections



Figure 1. Intubated patient with facial burns. Informed consent was obtained from the patient for the publication of this image.

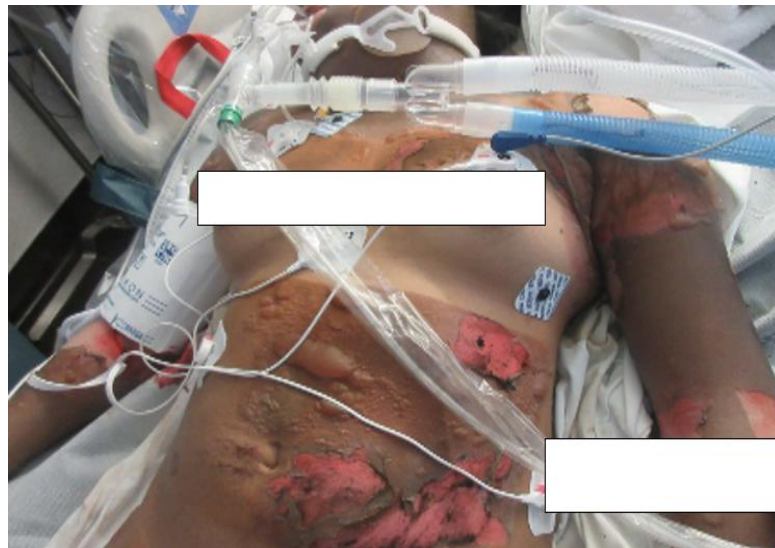


Figure 2. Third-degree burns affecting anterior torso, anterior abdominal wall, and bilat upper extremities. Informed consent was obtained from the patient for the publication of this image.



Figure 3. Third-degree burns on posterior torso and back. Informed consent was obtained from the patient for the publication of this image.



Figure 4. Third-degree burns affecting the back of the patient’s bilateral lower extremities. Informed consent was obtained from the patient for the publication of this image.

Table 2. Burn type estimation.

Method	Description	Body Regions	TBSA (%)
Rule of Nines	Developed by A.B. Wallace in the 1950s, this method estimates TBSA for burn injuries in adults.	Head and neck	9%
		Each arm	9%
		Each leg	18%
		Anterior trunk	18%
		Posterior trunk	18%
	Note: For pediatric patients, modifications are necessary, as the head and neck proportion is larger.		
Palmer Method	Uses the patient’s hand as a reference to estimate burn size, particularly for small or scattered burns.	Palmar surface (including fingers and palm)	~1%
Lund-Browder Chart	Introduced in 1942, this chart provides a more precise method, accounting for age-related anatomical differences.	Adjusts body region percentages based on the patient’s age—especially useful for pediatric cases.	Varies by age and body region.

4. Transfer Criteria to a Burn Center

Burn centers provide comprehensive care, including advanced wound management, critical care, and rehabilitation. Therefore, timely transfer to a specialized burn center is critical for optimal outcomes. In addition to severe burns, transfer should also be considered for patients with poorly controlled pain, burns to the face, hands, genitals, or large joints, burns complicated by comorbid conditions, and patients requiring specialized social, emotional, or rehabilitative interventions. Additional transfer criteria include pressure injuries and skin conditions such as bullous pemphigoid, Stevens–Johnson syndrome, toxic epidermal necrolysis, and non-healing diabetic wounds.

To ensure patient safety during transfer and improve overall outcomes, several steps need to be taken at the referring facility, including securing the airway if needed, establishing reliable vascular access, inserting a Foley catheter to monitor hourly urine output, initiating fluid resuscitation, and stabilizing other trauma-associated injuries prior to transfer. Sterile dressings should be applied over burn wounds, and the patient should be covered with a blanket to prevent hypothermia [5].

5. Establishing IV Access

Patients with extensive burns arrive at the emergency room awake but severely agitated due to pain, which makes IV access challenging. Access through limited unburned skin may necessitate the use of ultrasound-guided central venous access, with particular attention to sterile technique, as these patients are at high risk for delayed infections. IV access through an overlying burn is not contraindicated but can be technically challenging due to tissue edema and the loss of local landmarks. In emergencies, intraosseous access is a viable alternative.

6. Airway Management in Burn Care

Significant heat exposure can cause rapid swelling of the posterior oropharynx, tongue, vocal cords, and subglottic space, which can worsen with fluid resuscitation (Figure 5). Early evaluation and securing of the airway are critical in the initial management phase. Airway injury should be suspected in patients presenting with hoarseness, dysphagia, difficulty clearing secretions, severe cutaneous burns involving 40–50% of TBSA, or extensive, deep facial burns. Signs of impending airway obstruction include stridor, accessory muscle use, nasal flaring, sternal retractions, and decreased level of consciousness [6,7].



Figure 5. Swelling of tongue and oropharynx following facial burns. Informed consent was obtained from the patient for the publication of this image.

For suspected inhalational injury without clear indications for intubation, flexible fiberoptic laryngoscopy or bronchoscopy is recommended upon admission to evaluate the upper airways. Findings such as significant edema, blisters, or ulcerations warrant airway stabilization. Intubation may require advanced airway techniques, such as direct laryngoscopy with a rigid blade to displace edematous tissues for optimal visualization. Sedative agents like ketamine or opioids may be used to maintain spontaneous ventilation, while paralytics should be avoided, as they inhibit spontaneous respirations and risk the inability to ventilate if intubation fails. Succinylcholine is contraindicated in the first 24 h due to the risk of hyperkalemia. Rescue airway plans, including laryngeal mask airways (LMA) or surgical cricothyroidotomy, must be ready in case of failed intubation [6,7].

Once intubated, the endotracheal tube (ETT) should be circumferentially secured with umbilical ties, as adhesive tapes are ineffective on burned skin. The ETT cuff should use minimal air to reduce mucosal ischemia. Additional work-up includes arterial blood gas (ABG) analysis with co-oximetry and lactic acid to detect potential cyanide poisoning from burning textiles or plastics, which may require IV hydroxycobalamin treatment [8]. Elevated carbon monoxide (CO) levels should be managed with 100% oxygen until carboxyhemoglobin levels drop below 5% [9].

Mechanical ventilation in smoke inhalation includes the initial setting of a 6 mL/kg tidal volume based on ideal body weight, a PEEP of 5 cm H₂O, and plateau pressures below 30 cm H₂O. Early bronchoscopy is essential to assess inhalational injury severity using the Abbreviated Injury Score (AIS) [10] and enables soot removal through lavage (Table 3, Figures 6–8). Repeat bronchoscopies may be necessary to evaluate recovery progress [11]. The treatment regimen for smoke inhalation injury includes nebulized medications such as scheduled albuterol (2.5 mg/3 mL), 20% N-acetylcysteine inhalation solution, and inhaled heparin (10,000 U in 3 mL normal saline) administered every four hours, combined with airway clearance techniques [12]. Extubation readiness depends on airway patency, secretion clearance, and the AIS grade. Post-extubation, a high-flow nasal cannula may be used when facial burns make it challenging to use noninvasive ventilation via a tight-fitting mask [13]. Tracheostomy can be considered to facilitate ventilator weaning, although the timing and indications remain a topic of debate.

Table 3. Abbreviated Injury Score (AIS) bronchoscopic classification for inhalation injury categorizing the severity of airway burns based on bronchoscopic findings.

Grade	Bronchoscopic Findings	Description
Grade 0	Normal airway	No evidence of inhalation injury
Grade 1	Mild erythema and edema	Minimal mucosal damage, no soot deposition
Grade 2	Moderate erythema, edema, and soot deposition	Mild mucosal sloughing, early airway obstruction possible
Grade 3	Severe erythema, edema, and mucosal sloughing	Airway obstruction risk increases, ulceration present
Grade 4	Necrosis, severe mucosal sloughing, bronchial obstruction	High risk of respiratory failure and long-term complications

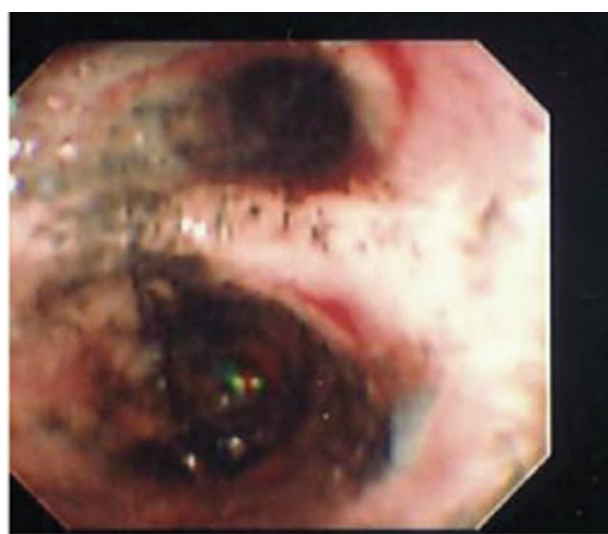


Figure 6. Bronchoscopy findings on post burn day 0.

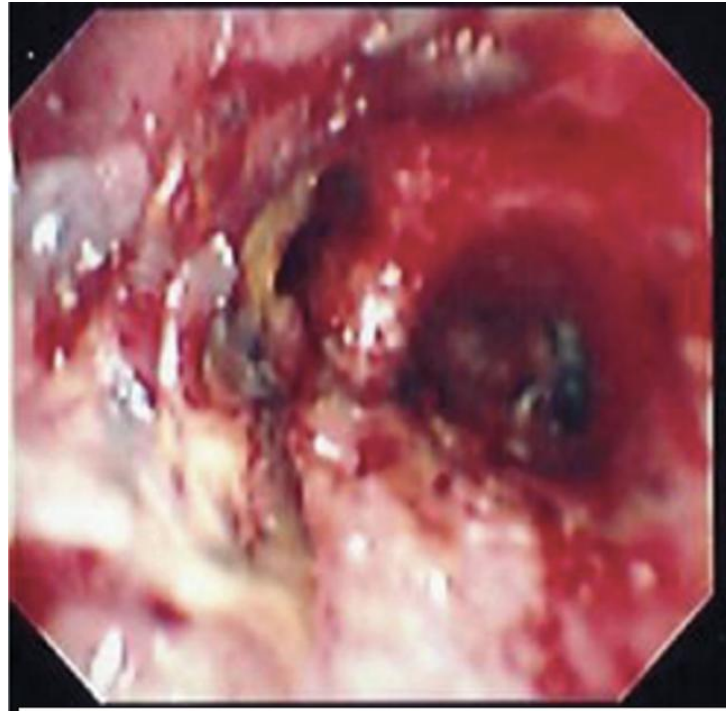


Figure 7. Caption. Bronchoscopy findings post burn day 4.



Figure 8. Caption. Bronchoscopy findings on post burn day 8.

7. Fluid Resuscitation in Burn Care

Severe burn injuries result in increased vascular permeability, capillary leakage, and inflammation, which cause significant fluid shifts. Effective management focuses on maintaining adequate tissue perfusion while minimizing complications of fluid overload, such as ARDS, abdominal compartment syndrome (ACS), and fluid creep. Initial resuscitation begins at 2 mL/kg/% TBSA (Parkland formula) for burns exceeding 20% TBSA, typically using Ringer's Lactate due to its physiological compatibility. Fluid administration is guided by urine output (targeting 0.5–1 mL/kg/h) and hemodynamic parameters [14]. The American Burn Association (ABA) recommends introducing albumin within the first 24 h in cases

of hemodynamic instability to reduce fluid requirements. However, early administration (within the first 12 h post-burn) is discouraged due to the risk of pulmonary edema [15].

One of the main issues determining mortality in patients with severe burns is fluid resuscitation. If insufficient fluid therapy is administered, the patient may enter acute kidney failure within 1–2 days. Conversely, if fluid resuscitation is overly aggressive, the patient may develop acute pulmonary edema within 24 h followed by respiratory distress that requires mechanical ventilation. Adequate, but not excessive, fluid resuscitation decreases mortality and morbidity [4].

Selective monitoring of intra-abdominal pressure (IAP) is recommended for patients with massive burns, projected 24 h fluid volumes exceeding 6 mL/kg/% TBSA or 250 mL/kg, or clinical signs of abdominal compartment syndrome [15].

Innovations such as computerized decision support systems (CDSS) have improved fluid titration and reduced total resuscitation volumes compared to traditional methods using urine output alone. While high-dose vitamin C shows promise in promoting diuresis and reducing fluid requirements, concerns about osmotic diuresis, dehydration, and oxalate nephropathy remain unresolved. The use of fresh frozen plasma (FFP) in early burn resuscitation lacks sufficient evidence [14]. Although vasopressors may be required for refractory hypotension, there is insufficient data regarding the choice of vasopressors in burn patients [16].

Advanced therapies, such as continuous renal replacement therapy (CRRT), are being explored for their potential benefit in removing inflammatory cytokines via diffusion, but they are not yet standard practice. A randomized controlled trial (RESCUE) evaluating CRRT in burn patients with septic shock and acute kidney injury suggested a reduction in vasopressor dependency at 48 h [17]. However, the findings lack broad applicability due to insufficient data. Balancing the risks of under- and over-resuscitation requires a personalized approach guided by established protocols and close monitoring of patients.

Systemic oxidative stress and systemic inflammation may occur in burns covering over 20% of TBSA. Early debridement of the burn wound, wound dressing with antioxidant activity, and adequate fluid therapy can prevent these adverse conditions [18–20].

8. Pain, Agitation, and Delirium Management

Pain is a common problem in burn care, arising from both the burn injury itself and the pain associated with required serial surgical treatments and dressing changes. Post-operative pain can involve the primary injury site as well as the donor site of a skin autograft. ABA recommendations advocate for a daily, standardized assessment of pain and consistent communication between the physician and nursing staff to ensure that pain is adequately managed [21]. A multi-modal approach that includes acetaminophen, non-steroidal anti-inflammatory drugs (NSAIDs), gabapentinoids, and opioids can provide a variety of pharmacologic mechanisms and dosing frequencies to deliver sustained and effective relief [22]. ABA recommendations also include utilizing the lowest effective daily morphine-equivalent opioid dose, although it is worthwhile to note that patients with burns often need higher doses of pain medications than are typically used in other circumstances. The opioid dose should also be continually reassessed and adjusted according to individual patient needs over the course of the hospitalization. If local expertise is available, regional anesthesia can provide pain relief to an affected limb and assist in reducing the amount of systemic analgesia required [23]. Adjunctive burn therapies, such as hyperbaric oxygen, can decrease tissue swelling and the associated pain.

In addition to scheduled acetaminophen, NSAIDs, gabapentinoids, and oral opioids, the management of breakthrough pain often necessitates intravenous opioids. Other medications that can address severe post-operative pain and the pain accompanying

dressing changes include ketamine and lidocaine infusions. For patients who are very opioid-tolerant, methadone can provide another option, although caution and experience are warranted given its long half-life and non-linear morphine equivalence [24].

Agitation due to delirium after burn injury is frequently seen in the early period of admission to the burn unit. Agitation should be thoroughly evaluated to exclude other medical causes of behavioral disturbances, such as head injury, drug intoxication or withdrawal, and primary psychiatric problems.

Once underlying medical issues have been addressed, as-needed treatments for agitation due to delirium include antipsychotics like haloperidol, olanzapine, and ziprasidone. In the ICU, dexmedetomidine infusion can reduce behavioral disturbances without suppressing the respiratory drive and can help ease the transition from intubation to the post-extubation period [25]. A psychiatry consultation can help tailor a medication regimen to individual patient needs and histories of psychiatric disorders, such as the need for alternative mood-stabilizing medications that are not QT-prolonging (such as valproate). Benzodiazepines can be administered for patient safety but carry the risk of perpetuating delirium, especially in elderly patients. Melatonin can help promote sleep, and other non-pharmacologic interventions to enforce a regular sleep/wake cycle are also beneficial in preventing delirium [26].

9. Nutritional Support in Burn Patients

Extensive burns result in a severe and prolonged hypermetabolic and hypercatabolic state [27,28]. The elevated cortisol and epinephrine from the stress response result in an elevation in resting energy expenditure [29]. Aggressive nutritional support is needed to meet these increased metabolic demands, accelerate wound healing, and decrease infection and mortality risks [30]. This increase in energy requirement is correlated with burn size, and factors such as agitation, pain, and heat loss during dressing changes further contribute to a significant increase in energy expenditure [31]. As in all aspects of burn care, a multidisciplinary approach provides the best level of care. To that end, we recommend working closely with a dietitian specialized in burn care.

We monitor nutritional markers twice a week, including prealbumin, C-reactive protein, and liver function tests. Prealbumin is a less sensitive marker during the acute phase of the burn; however, as the acute phase subsides (correlating with a decrease in C-reactive protein), prealbumin (half-life: 48–72 h) is expected to increase with adequate nutrition [32]. Persistently low prealbumin levels in the presence of normalizing C-reactive protein may be a sign of protein or calorie deficiency.

Given the association with decreased mortality in some studies, we start enteral nutrition within 4–6 h for large burns (TBSA > 20%) with the goal of supplying (25 kcal/ideal body weight) + (40 kcal/% TBSA) via the Curreri formula (although this can overestimate caloric needs) [33]. The rate of carbohydrate at 7 g/kg/day is the maximal rate at which glucose can be oxidized in severely burned patients [34]. With protein requirements directly related to burn size, we aim to provide between 1.5 and 2 g/kg/day of protein [35]. Enteral feeds should not be interrupted unless residuals are greater than 500 mL, accompanied by signs of nausea/vomiting or abdominal distention [36]. If necessary, the early use of a promotility agent such as metoclopramide can help facilitate nutritional requirements. When patients can eat on their own, we transition to nocturnal enteral nutrition for 12 h at night, aiming to meet 60% of their caloric requirements. Enteral feeds are discontinued when the patient can eat at least 75% of their nutritional requirements.

In all patients with burns covering more than 10% TBSA, we administer standard doses of multivitamins, vitamin C, and zinc [37,38]. In general, however, supplement studies have been of low quality. For instance, while glutamine exhibited some initial

promise, it was later revealed that glutamine was not beneficial in a randomized trial involving burn patients [39].

10. Diagnosis and Treatment of Infections in Hospitalized Burn Patients

Infection is the leading cause of mortality in burn patients after the immediate resuscitation period. Local wound infections and bacteremia/fungemia are of particular concern in hospitalized burn victims.

The burn wound bed is an ideal environment for bacterial and fungal contamination, biofilm formation, and local and/or systemic infections from these organisms. The larger and deeper the burn, the greater the risk. These large burns are also associated with prolonged hospitalizations and inflammatory states, both of which put patients at risk for wound-related and other nosocomial infections [40,41].

10.1. Timeline and Common Micro-Organisms

In general, for the first 4 days, burn wounds are sterile, with colonization of the wounds usually occurring 5–7 days post-burn [42]. In the first week after the burn injury, the main wound infections are cellulitis related to contamination of the wound by Gram-positive organisms from the surrounding skin. After the first week, there is an increasing risk for multi-drug-resistant (MDR) Gram-negative organisms, and after a few weeks, there is a risk for systemic fungal infections [43]. In large series from burn centers across the country, the most common bacterial wound culture isolates during the hospitalization of burn patients are *Staph aureus*, but an additional significant percentage of isolates also grow *Pseudomonas* or *Acinetobacter* species. Other commonly isolated bacteria include group A *Strep*, *E coli*, *Klebsiella*, and other gram-negative rods [43]. Increased infection risks are associated with the size and depth of the burn, the patient's age, and other comorbidities. Contamination or colonization with microorganisms should be monitored carefully through wound inspection and repeated cultures when indicated.

Pseudomonas infection can often be suspected based on malodorous and yellow or green discolored wounds. *Acinetobacter* is commonly multi-drug resistant and can be easily transmitted by fomites to other patients. Strict isolation procedures should be followed closely for *Acinetobacter* infection and other multidrug-resistant organisms (GNR and MRSA).

Fungemia is a particular danger, and risks for this infection include central lines, diabetes, and TPN. This infection typically appears later in the hospital course and is often unsuspected until detected through surveillance blood cultures. High mortality is associated with systemic fungal infections.

10.2. Diagnosis and Treatment

Cellulitis and infected eschar can be noted upon examination of the burn. Cellulitis is suspected when erythema extends beyond the skin borders typically associated with the injury. Infected eschar is often discolored. Graft loss can also be a sign of a local infection.

Signs of systemic infection (bacteremia and fungemia), however, can be difficult to recognize. Many burn patients with TBSA burns greater than 20% will exhibit ongoing signs of systemic inflammation during their hospital course that mimic sepsis. Published "sepsis" criteria are less sensitive or specific for this population, and bedside clinicians should be alert to any changes in hospital baseline vital signs, lab tests, and other signs of organ dysfunction that suggest a new infection [44].

Burn wounds are typically cultured upon admission, with repeat cultures obtained for any clinical changes and/or changes in wound appearance. Many centers screen nasal swabs for MRSA colonization, as it is closely associated with the presence of this resistant

organism in the wound [45]. Empiric treatment with anti-microbials is often needed when there is uncertainty about infection but still clinical concern. Covering suspected pathogens is important (often using prior cultures if they demonstrate colonization with MDR organisms) when selecting antimicrobial agents, while also de-escalating or stopping these agents after confirming the specific infection and/or completing a course of treatment. It is important to avoid prolonged or unnecessary antibiotic treatment, which promotes worsening resistance issues.

Wound debridement is a fundamental part of local wound infection treatment and prevention, both surgically and through washing and bedside dressings as appropriate. Early wound excision of all full-thickness wounds is attempted in all patients during the first week of hospitalization (provided they are medically stable for this procedure). Prompt surgical debridement is also necessary for any infected eschar [46].

Attention should be paid to early central venous, arterial, and bladder catheter removal, as well as to pneumonia prevention strategies for all patients [47,48]. Central lines should be inserted as far as possible from burn wounds (avoiding the femoral site when possible). Although scheduled line changes have not been found to be effective in reducing complications in general ICU patients, many burn programs recommend changing the central line site every 3–7 days to reduce central line infections (based on limited data) [49].

Burn patients are at particular risk for nosocomial infections given their prolonged hospital stays and sustained inflammatory state. A structured approach to preventing, diagnosing, and treating infections in hospitalized burn patients should be followed to minimize these complications.

11. Preoperative Medical Management

After the initial resuscitation and stabilization, early surgical excision and grafting are critical. Prompt surgical treatment for large burn patients improves healing and reduces infection risks. Burn surgery is urgent and time-sensitive, particularly for large burns, and should ideally occur within the first few days of hospitalization [50].

For burns > 20% of the total body surface area (TBSA), however, a delay of 24–48 h (or longer) may be necessary for fluid resuscitation and stabilization. Medical consultants must also balance optimizing preexisting conditions against delaying surgery.

Large burn surgeries involve significant fluid shifts and considerable blood loss [51]. All patients should have a type and screen performed, and blood products should be available in the operating room as needed.

General anesthesia may cause vasodilation and worsen hypotension, especially in under-resuscitated patients. Adequate vascular access (possibly through a central venous catheter) and arterial line placement may be necessary for monitoring during the peri-operative period.

Preoperative evaluation includes a detailed medical history and physical examination, with particular attention to symptoms and signs of preexisting cardiac, neurologic, and pulmonary disease. Home medications should be carefully reviewed, and any previous issues with anesthesia or the peri-operative course should also be reviewed. Standard preoperative lab tests often include kidney and liver function tests, hematocrit, platelets, and pregnancy testing in women of childbearing age. Patients with cardiac risk or advanced age should undergo an EKG, and a CXR is recommended for those with pulmonary disease or a BMI > 40 [52].

Cardiac risk should be assessed using validated scores, such as the Revised Cardiac Risk Index (RCRI), and functional capacity should be established from the history (e.g., acceptable functional capacity is the ability to achieve four metabolic equivalents (METs) of work without symptoms). Examples of exercise to achieve at least four METs

of work include climbing >2 flights of stairs without stopping. Stable patients with RCRI scores of ≤ 1 or good functional capacity (>4 METs) can proceed with surgery. A cardiology consultation is advised for RCRI scores >3 or poor functional capacity. Some guidelines also incorporate biomarkers (e.g., BNP) for assessing cardiac risk [53]. Patients with newly detected cardiac murmurs, dyspnea, and edema should undergo echocardiography.

Perioperative medications should be carefully reviewed for burn surgeries. Older adults are at risk for delirium from opioid pain medications and other sedating medications, necessitating careful use. Anti-cholinergic agents can also exacerbate delirium in this age group [54]. Substance use screening helps anticipate tolerance or withdrawal. Patients with obstructive sleep apnea (OSA) should have postoperative precautions, including non-supine positioning and PAP therapy [55].

Decisions regarding the continuation of home anticoagulants should be discussed with the surgical team, with hematologist or cardiologist input if needed. Most conditions (other than certain mechanical valves or hypercoagulable states) do not require “bridging” anticoagulation, but bleeding risks must be balanced. Anti-platelet therapy for recent cardiac stents should be carefully considered [56]. Most chronic medications, like thyroid drugs, anti-glycemic medications, and steroids, should be continued, with possible dose adjustments as needed postoperatively.

Effective perioperative care requires close coordination among the medical, surgical, and anesthesia teams to optimize outcomes.

12. Anemia and Blood Transfusions in Burn Patients

Anemia is very common in burn patients, persisting from the initial injury through hospitalization and even post-discharge. Several factors contribute to ongoing anemia, including critical illness, impaired erythropoiesis, hemolysis, and procedure-related blood loss [57,58]. Significant hemodynamic instability is frequently seen in severe burns, necessitating blood transfusions to maintain circulatory volume. Many clinicians believe that anemia, beyond a certain threshold, negatively affects skin graft success and burn wound healing. However, transfusions carry risks, including infections, transfusion-related lung injury, and immune suppression.

Factors contributing to anemia in burn patients are as follows:

- Hemolysis: Burns can cause red blood cell destruction due to oxidative stress, red blood cell membrane fragility, and microangiopathic hemolysis associated with critical illness.
- Critical illness and sepsis: Inflammation, reduced erythropoietin production, nutritional deficiencies, and decreased iron availability can contribute to anemia, especially in patients with prolonged ICU stays and ongoing infections.
- Blood loss anemia: Wound debridement, chronic wound bleeding, dressing changes, and ongoing blood draws all contribute to anemia in patients with large burns, who often require multiple transfusions.

Wound debridement, a key burn treatment, involves the removal of necrotic tissue to promote healing and reduce the risk of infection, but it can cause substantial bleeding. Various techniques, such as electrocoagulation, epinephrine-soaked dressings, compression, hemostatic agents (both topical and systemic), and, in some cases, extremity tourniquets, can help control intraoperative bleeding; however, post-surgical blood loss can still occur, often requiring preemptive transfusion [59].

Transfusion Strategies:

The optimal transfusion threshold remains a topic of debate. Historically, liberal transfusion practices maintained hemoglobin (Hb) levels between 10 and 12 g/dL; however, recent studies support restrictive strategies (Hb between 7 and 12 g/dL) as equally

effective, demonstrating no decrease in complications, organ failure, or mortality [60–62]. Additionally, iron deficiency appears to be under-diagnosed in burn patients and may benefit from treatment with IV iron supplements [63,64].

Although optimizing medical, nutritional, wound care, and surgical treatments can minimize blood loss, severely burned patients may still require substantial transfusions to address acute surgical blood loss and the blunted erythropoiesis associated with the anemia of critical illness.

13. Psychological Aspects of Burn Care

Psychological distress is a frequent and debilitating complication of severe burn injury, especially in individuals with pre-existing mental health issues, substance use disorders, or untreated psychological conditions. Psychological needs must be addressed early, from the point of admission through long-term rehabilitation [65]. It is recommended to obtain a psychological history, including any history of substance abuse, personality disorders, and a list of current psychiatric medications at the time of admission. Consider ordering a urine toxicology screen if substance abuse is suspected. Assess the level of family involvement in the patient's care, which can be critical for psychological support. Ensure that psychiatric medications are continued during the hospital stay. During the intensive care phase, psychological interventions are geared toward immediate concerns such as managing sleep disturbances, controlling pain, and using family members to convey hope to the patient. Delirium and brief psychotic reactions are common during this phase. As the patient stabilizes and becomes more alert, they begin to recognize their burns' full physical and psychological impact. At this stage, depression, anxiety, and sleep disturbances become common. Treatment during this stage should include optimal pain management as well as medications for anxiety, depression, and sleep support [66–69]. The first year post-hospitalization is a period of high psychological distress, with challenges including itching, limited endurance, decreased function, body image issues, and returning to work. After discharge, the focus shifts to reintegration into society, with ongoing physical rehabilitation, outpatient counseling, social skills training, and peer counseling to help navigate this period.

14. Surgical Management of Burn Wounds: Types of Grafts and Dressings in Burn Care

Surgical management of burns is a complex yet critical aspect of burn care that requires careful assessment and intervention to minimize morbidity and optimize recovery. Along with medical management aimed at optimizing the patient's condition, surgical debridement and closure of burn wounds lead to a significant decrease in hypertrophic burn scars/contractures and better patient outcomes. Surgeons must make decisions based on the burn's depth, size, location, and the patient's overall condition. While there is an array of products and nuances in the surgical management of burns, not all of which will be discussed, an overview of commonly employed surgical techniques is provided below [70].

14.1. Debridement

- **Timing:** Early debridement within 24–72 h of a burn injury is recommended to prevent infection, decrease systemic response, and optimize graft success if the patient is stable for surgery.
- **Method:** Surgical debridement is the gold standard method for removing dead tissue, but enzymatic debridement can be used as an adjunct or in lieu of surgical debridement, particularly when dealing with complex patients or if there is a delay in surgery. Two notable enzymatic debridement agents approved by the FDA are Collagenase

Santyl [71] ointment and Nexobrid [72] (which contains a mixture of enzymes from pineapple plants), both of which show promise as alternatives to surgical debridement.

14.2. Skin Grafting

Following debridement, the goal of wound healing is to cover the burn wounds with skin substitutes, which promote healing by providing a viable skin barrier, preventing fluid loss, and minimizing infection risk. Biologic skin substitutes are as follows:

- Homograft (cadaver skin): Also known as allografts, cadaver skin is used as a temporary biological dressing in preparation for split-thickness skin grafts (autografts).
- Xenografts: Biological dressings (e.g., porcine skin) are used for superficial burns (likely to heal without autografts) or to prepare wound beds.
- Autografts: Allografts and xenografts are ultimately rejected by the patient's immune system and need to be removed and replaced with definitive wound treatments, i.e., autografts. Split-thickness skin grafts (harvested from the patient) are meshed to cover wounds. Immobilization after autografts is typically warranted. Takedown of sites typically occurs 72 h post-surgery.

14.3. Tissue Engineering

Over the last few decades, tissue engineering has offered a promising solution to the challenges of covering large burn areas with grafts, particularly when limited by the lack of availability of donor skin. It uses special materials called scaffolds, which act as a framework to support new growth. These scaffolds are seeded with stem cells, such as mesenchymal stem cells (MSCs) and induced pluripotent stem cells (iPSCs) [73], or with skin or synthetic cells to speed up healing, with common examples including Integra [74], NovosorbTM BTM [75], and Recell [73,76].

- Stem cells: The ability of stem cells to regenerate and differentiate into various cell types makes them uniquely able to replace tissues. Recently, scientists have started using co-cultured cells—combining different types of cells—along with advanced 3D models to create artificial tissues that closely resemble natural ones.
- Integra: As a biological skin substitute, it is a two-layer membrane consisting of a porous collagen layer (dermal analogue) bonded to a thin silicone layer (temporary epidermis). The dermal layer becomes revascularized and populated by the patient's own cells from the underlying tissue over 7–21 days. Once this process is complete, the silicone layer is removed and replaced with an ultrathin split-thickness skin graft (autograft).
- NovoSorbTM: It is a synthetic wound dressing that provides a temporary scaffold over the excised area for new tissue to grow over 2–4 weeks. It is usually used on deep and complex wounds, and its synthetic nature reduces the risk of bacterial colonization.
- Recell (epidermal autograft): A small amount of the patient's harvested skin is processed to extract the epidermal cells. These epidermal cells are suspended in a buffer solution and sprayed over the excised areas as grafts. Recell can also be used without an autograft but is limited to sites with good dermis in more superficial second-degree burns. The use of Recell improves healing times, minimizes scarring, and improves pigmentation.

14.4. Advanced Burn Wound Dressings

Specially designed wound coverings create a moist environment, which is essential for proper wound repair, and include added features to prevent infection and reduce pain. Common examples are as follows:

- Hydrogel and Bioactive Dressings [77]: These dressings provide moisture and cooling, promote healing, and can be infused with antimicrobials, growth factors, or nanoparticles.
- Silicone-based Dressings [78]: These dressings help reduce hypertrophic scarring and improve aesthetic outcomes; however, they are difficult to keep in place at the joints and areas with a high range of motion.
- Smart Dressings [79]: Sensors embedded in dressings can monitor infection, temperature, and hydration levels in real time, allowing for early intervention.

15. Conclusions

This review highlights the multifaceted management of severe burn injuries, from initial resuscitation and airway management to surgical interventions, nutritional support, and psychological care. Care for burn patients has greatly improved due to enhanced diagnostics and treatment protocols, but managing infections and anemia alongside the hypermetabolic response of extensive burns continues to pose significant challenges. The combination of early surgical debridement and grafting, along with careful wound care, plays an essential role in minimizing complications and enhancing functional recovery. Holistic treatment of burn injury patients requires attention to their psychological well-being to promote complete physical and emotional recovery. Successful burn recovery necessitates a personalized, evidence-based treatment plan that relies on multidisciplinary team support to manage the complex recovery path. Ongoing research advancements in burn treatment will lead to better patient results while decreasing complications and enhancing survivors' quality of life.

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